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**FINAL TECHNICAL REPORT**

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**Development of Analytical and  
Environmental Diagnostic Techniques**

**GC-FR-2834**

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**As Required by  
Contract Number N00014-95-C-2054**

***Prepared for***  
U.S. Naval Research Laboratory  
4555 Overlook Avenue, S.W.  
Washington, DC 20375-5326

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## 1.0 INTRODUCTION

This Final Report lists the publications and presentations generated and/or the accomplishments made – for the diverse tasks performed by GEO-CENTERS, INC. in support of the Naval Research Laboratory (NRL) Contract Number N00014-95-C-2054, during the period of September 1995 to September 1999. The work includes tasks designated in the original Statement of Work, as well as additional tasks that were later appended to the existing contract. The specific tasks include the following:

- Analysis and Control of Airborne Chemicals.
- Chemical Analysis and Chemical Sensor Development
- Environmental Remediation Site Characterization
- Airborne and Marine Magnetic Site Characterization

## 2.0 SCOPE

These research efforts require the expertise of skilled, highly-technically qualified contractor scientists and engineers in support of the Branch obligations to carry out these chemical development studies. The range of skills required for these studies includes laser studies, optical spectroscopies, mass spectrometry, reaction kinetics and mechanisms, modern instrumental analytical technique development and applications, advanced chemical sensor development, computer modeling and graphics, software development, sophisticated data reduction and analysis, generation of briefings and reports for sponsors and hardware design and system engineering experience.

The R&D requirements include tasks that vary considerably in their scope and in the complexity of the deliverable products. However, the tasks are interrelated in that they support the central mission of the Branch and must be coordinated with each other.

### **3.0 TASK DESCRIPTIONS**

#### **3.1 TASK 1 – ANALYSIS AND CONTROL OF AIRBORNE CHEMICALS**

##### **Technical Requirements**

- (1) The contractor shall use standard analytical methods and techniques for the characterization of trace organic components from submarine atmospheres.
- (2) The contractor shall investigate and develop new technologies that will be used in obtaining information about trace organic levels aboard submarines.
- (3) The contractor shall analyze the results of atmospheric chemical measurements made on operational submarines.
- (4) The contractor shall undertake laboratory chemical studies to investigate gas phase chemical reactions. These studies shall be conducted to determine the environmental fate and affect of the use of replacement refrigerants and their reactive products on machinery, instrumentation, electronics and personnel in ship and submarine environments.
- (5) The contractor shall design test protocols, support field studies, evaluate results and draft reports describing performance.

##### **Accomplishments**

Analyzed samples acquired from submarines, USS KENTUCKY, USS BOISE and USS WEST VIRGINIA. Canister samples and adsorbed tube samples were analyzed by thermal desorption gas chromatography/mass spectrometry. Analysis of the resultant chromatograms

indicated the presence of several volatile organic compounds, including benzene, toluene, xylene and chlorinated hydrocarbons.

Other laboratory activities included the analysis of polyol ester lubricants and the characterization of gases from oil samples taken from hydraulic systems aboard submarines. The latter were characterized by gas chromatography using flame ionization and thermal conductivity detection.

### **3.2 TASK 2 - CHEMICAL ANALYSIS AND CHEMICAL SENSOR DEVELOPMENT**

#### **Technical Requirements**

- (1) The contractor shall investigate standard techniques and modifications of standard techniques that can be employed in the characterization of water from shipboard waste streams.
- (2) The contractor shall explore and develop new technologies to be used in the characterization of water from shipboard waste streams.
- (3) The contractor shall evaluate available technologies and develop new sensors and monitoring capabilities suitable for monitoring effluents from shipboard solid waste treatment facilities.
- (4) The contractor shall undertake development of alternate concepts for solid waste treatment techniques appropriate for shipboard use.
- (5) The contractor shall design and support field test protocols as required. The contractor shall compile and analyze data, prepare reports and briefings as directed.

**Publications (18)**

"Shock Test Report on the Closed Loop Cooling Unit," GEO-CENTERS' letter serial number 97-081, June 1977, submitted to SEA 03R16, SEA 03L1 and NSWCCD Bethesda (Code 634).

Sean Gill, "Shock Test Report on the Solid Waste Management Equipment," GEO-CENTERS letter serial number 97-055, 25 April 1997, submitted to SEA 03R16, SEA 03L1 and NSWCCD Bethesda (Code 634); copy provided to NSWCCD-SSES on 6 May 1997.

"Solid Waste Equipment Shock Test Plan of Action and Milestones," issued to SEA 03R16 and SEA 03L1.

Final Report on "DD 988 Shipboard Evaluation Graywater System Safety Analysis," issued to NSWCCD Bethesda.

W. Drosjack, "CFD Model Study of the US Navy Waste Incinerator," submitted to NSWCCD Bethesda.

M.T. Montgomery, T.J. Boyd, B.J. Spargo, R.B. Coffin, **J.K. Steele**, D.M. Ward, and D.C. Smith, "Bacterial Assemblage Adaptation In PAH-Impacted Ecosystems," *In Situ and On-Site Bioremediation*, B.C. Alleman and A. Leeson (eds.), Battelle Press, Columbus, OH, Vol. 5(8):223-228 (1999).

T.J. Boyd, M.T. Montgomery, B.J. Spargo, and **J.K. Steele**, "PAH Distribution and Biodegradation in the Delaware and Schuylkill Rivers," *In Situ and On-Site Bioremediation*, B.C. Alleman and A. Leeson (eds.), Battelle Press, Columbus, OH, Vol. 5(8):295-300 (1999).

T.J. Boyd, M.T. Montgomery, B.J. Spargo, R.B. Coffin, **J.K. Steele**, J.P. Pohlman, and D. Velinsky, "Characterization of Intrinsic Bioremediation within the Philadelphia Naval Complex Reserve Basin," NRL Technical Report, NRL/PU/6115-99-374 (1999).

R.B. Coffin, **J.W. Pohlman**, and **C.S. Mitchell**, "Fate and Transport of PAH and Metal Contaminants in the Anacostia River Tidal Region," NRL Memorandum Report, NRL/MR/6110-99-8327 (1999).

R.B. Coffin, M. Orr, E. Carey, L.A. Cifuentes, and **J. W. Pohlman**, "Contaminant Distribution and Fate in Anacostia River Sediments: Particulate Transport Survey," NRL Memorandum Report, NRL/MR/6110-98-8139 (1998).

**M.T. Montgomery**, B.J. Spargo, and T.J. Boyd, "Ecosystem Level Evaluation of Intrinsic Biodegradation at Naval Shipyards and Impact on Adjacent Ecosystems: A Preliminary Report," NRL Technical Memorandum Report, NRL/MR/6115-98-8140 (1998).

B.J. Spargo, **M.T. Montgomery**, T.J. Boyd, R.B. Coffin, L.A. Cifuentes, J.G. Mueller, and W.W. Schultz, "In Situ Bioremediation and Efficacy Monitoring SERDP Project CU-030," NRL Technical Memorandum Report, NRL/MR/6115-98-8179 (1998).

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S.E. Lantz, **M.T. Montgomery**, W.W. Schultz, P.H. Pritchard, B.J. Spargo, and J.G. Mueller, "Constituents of Organic Wood Preservatives that Inhibit the Fluoranthene Degrading Activity of Bacterial Strain *Sphingomonas Paucimobilis* Strain EPA505," Environ. Sci. Technol. 31:3573-3580 (1997).

B.J. Spargo, R.B. Coffin, **M.T. Montgomery**, J. Jones-Mehan, and C. Kelley, "Exploiting Microbiology to Enhance Biodegradation of Hydrocarbon-Contaminated Environments," NRL Review, NRL/PU/5230-97-320, April, pp. 74-77 (1997).

**M.T. Montgomery**, T.J. Boyd, B.J. Spargo, J.G. Mueller, and R.B. Coffin, "Bacterial Productivity in BTEX- and PAH-Contaminated Aquifers," In Situ and On-Site Bioremediation, B.C. Alleman and A. Leeson (eds.), Battelle Press, Columbus, OH, Vol. 4(4):125-130 (1997).

T.J. Boyd, **M.T. Montgomery**, and B.J. Spargo, "Utilization Rates of Benzene and Toluene from a BTEX-Contaminated Aquifer," In Situ and On-Site Bioremediation, B.C. Alleman and A. Leeson (eds.), Battelle Press, Columbus, OH, Vol. 4(2):399-404 (1997).

R.B. Coffin, **M.T. Montgomery**, C.A. Kelley, and L.A. Cifuentes, "Assessment of Nutrient-Contaminant Carbon Ratios for Enhancing *in situ* Bioremediation," In Situ and On-Site Bioremediation, B.C. Alleman and A. Leeson (eds.), Battelle Press, Columbus, OH, Vol. 4(4):297-404 (1997).

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M.T. Montgomery, T.J. Boyd, **J.K. Steele**, D.M. Ward, D.C. Smith, B.J. Spargo, R.B. Coffin, **J.W. Pohlman**, M. Slenska, and J.G. Mueller, "Measuring Intrinsic Bacterial Degradation of PAHs in a Salt Marsh," presentation at the International Conference on Wetlands & Remediation, Salt Lake City, UT, November 16-17, 1999. (INVITED)



T.J. Boyd, M.T. Montgomery, J.G. Mueller, **J.K. Steele**, B.J. Spargo, R.B. Coffin, **J.W. Pohlman**, T. Demetriades-Shah, and M. Slenska, "Source Reduction Effect on Creosote PAH Bioremediation in Marsh Sediments," presentation at the Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 22-25, 2000. (INVITED)

T.J. Boyd, **J.W. Pohlman**, R.B. Coffin, M.T. Montgomery, B.J. Spargo, and **J.K. Steele**, "Coupling Contaminant Fate and Transport with Biodegradation: Is a Small Tidal Basin a Source or a Sink for Hydrocarbons," presentation at SETAC, Philadelphia, PA, November 16-18, 1999. (INVITED)

R.B. Coffin, T.J. Boyd, M.T. Montgomery, **J.W. Pohlman**, **C.S. Mitchell**, **J.K. Steele**, and B.J. Spargo, "Transport and Degradation of PAHs in the Tidal Region of the Anacostia River," presentation at SETAC, Philadelphia, PA, November 16-18, 1999. (INVITED)

K.S. Grabowski, D.L. Knies, T.M. DeTurck, D.J. Treacy, **J.W. Pohlman**, R.B. Coffin, and G.K. Hubler, "A Report on the Naval Research Laboratory AMS Facility," presentation at AMS-8 Conference, Vienna, Austria, 1999.

R.B. Coffin, K.S. Grabowski, I. MacDonald, L.A. Cifuentes, and **J.W. Pohlman**, "Analysis of Ocean Methane Hydrate Formation and Fate," presentation at the Conference of the American Society for Limnology and Oceanography, San Diego, CA, 1999.

B.J. Spargo, M.T. Montgomery, T.J. Boyd, and **J.K. Steele**, "Influence of the Tidal Cycle on Petroleum Biodegradation in Groundwater," presentation at the International Conference on Wetlands & Remediation, Salt Lake City, UT, November 16-17, 1999. (INVITED)

M.T. Montgomery, T.J. Boyd, B.J. Spargo, R.B. Coffin, D.M. Ward, **J.K. Steele**, and D.C. Smith, "Bacterial Assemblage Changes as an Ecological Impact Indicator on Ecosystems," presentation at the Fifth International Symposium on In Situ and On-Site Bioremediation, San Diego, CA, April 19-22, 1999.

T.J. Boyd, M.T. Montgomery, B.J. Spargo, and **J.K. Steele**, "PAH Distribution and Biodegradation in the Delaware and Schuylkill Rivers," presentation at the Fifth International Symposium on *In Situ* and On-Site Bioremediation, San Diego, CA, April 19-22, 1999.

R.B. Coffin, **J.W. Pohlman**, M.T. Montgomery, T.J. Boyd, J. Jones-Meehan, C.J. Kolanko, and B.J. Spargo, "Fate of PAHs in the Anacostia River Tidal Region," presentation at the Fifth International Symposium on In Situ and On-Site Bioremediation, San Diego, CA, April 19-22, 1999.

T.J. Boyd, M.T. Montgomery, B.J. Spargo, and **J.K. Steele**, "PAH Distribution and Biodegradation in the Delaware and Schuylkill Rivers," presentation at the Fifth International Symposium on In Situ and On-Site Bioremediation, San Diego, CA, April 19-22, 1999.

R.B. Coffin, **J.W. Pohlman**, M.T. Montgomery, and T.J. Boyd, "Transport and Fate of PAHs in the Anacostia River Tidal Basin," Federally Supported Science and the Chesapeake Bay Program, Patuxent National Wildlife Visitors Center, December 9-10, 1998.

M.T. Montgomery, T.J. Boyd, B.J. Spargo, R.B. Coffin, D.M. Ward, **J.K. Steele**, and D.C. Smith, "Bacterial Assemblage Changes as an Early Indicator of Ecological Impact of Military Operations on Industrialized Ecosystems," Partners in environmental technology symposium and workshop, Arlington, VA, December 1-3, 1998.

T.J. Boyd, M.T. Montgomery, B.J. Spargo, R.B. Coffin, D.M. Ward, **J.K. Steele**, and D.C. Smith, "Bacterial Assemblage Changes as an Early Indicator of Ecological Impact of Military Operations on Estuarine Sediments," presentation at the Workshop on Contaminated Sediment Management, Office of Naval Research and NAVFAC, San Diego, CA, October 14-16, 1998.

J.G. Mueller, F. Lakhwala, J. Carter, B. Spargo, **M.T. Montgomery**, and M. Brouman, "Economics and Performance of UVB Technology at a Creosote Site," presentation at Battelle's First international Symposium on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 18-21, 1998.

**M.T. Montgomery**, T.J. Boyd, B.J. Spargo, and D.C. Smith, "Heterotrophic Bacterial Production in the Waters and Sediments of Two PAH-Impacted Ecosystems near Charleston, SC and Philadelphia, PA (USA)," presentation at the 98th general meeting of the American Society for Microbiology, Atlanta, GA, May 16-20, 1998.

T.J. Boyd, **J.K. Steele**, **M.T. Montgomery**, and B.J. Spargo, "Biodegradation of PAHs in the Cooper River Estuary, Charleston, SC (USA)," presentation at the 98th general meeting of the American Society for Microbiology, Atlanta, GA, May 16-20, 1998.

**M.T. Montgomery**, T.J. Boyd, B.J. Spargo, J.G. Mueller, and R.B. Coffin, "Bacterial Productivity in BTEX- and PAH-Contaminated Aquifers," presentation at the Fourth International Symposium on *In Situ* and On-Site Bioremediation, New Orleans, LA, April 28-May 1, 1997.

**M.T. Montgomery**, T.J. Boyd, B.J. Spargo, J.G. Mueller, L.A. Cifuentes, C.A. Kelley, and R.B. Coffin, "Effect of a Groundwater Circulation Well on BTEX Degradation in a Gasoline Contaminated Aquifer," presentation at the 97th general meeting of the American Society for Microbiology, Miami, FL, May 11-14, 1997.

T.J. Boyd, **M.T. Montgomery**, B.J. Spargo, J.G. Mueller, C.A. Kelley, L.A. Cifuentes, and R.B. Coffin, "Effect of a Groundwater Circulation Well on PAH Degradation in a Creosote Contaminated Aquifer," presentation at the 97th general meeting of the American Society for Microbiology, Miami, FL, May 11-14, 1997.

T.J. Boyd, **M.T. Montgomery**, and B.J. Spargo, "Utilization Rates of Benzene and Toluene from a BTEX-Contaminated Aquifer," presentation at the Fourth International Symposium on *In Situ* and On-Site Bioremediation, New Orleans, LA, April 28-May 1, 1997.

R.B. Coffin, **M.T. Montgomery**, C.A. Kelley, and L.A. Cifuentes, "Assessment of Nutrient-Contaminant Carbon Ratios for Enhancing *In Situ* Bioremediation," presentation at the Fourth International Symposium on *In Situ* and On-Site Bioremediation, New Orleans, LA, April 28-May 1, 1997.

**M.T. Montgomery** and R.B. Coffin, "*In Situ* Bioremediation and Efficacy Monitoring," presentation at the 2nd Annual SERDP Symposium, Tysons Corner, VA, November 20-22, 1996.

**M.T. Montgomery**, R.B. Coffin, L.A. Cifuentes, J.G. Mueller, and B.J. Spargo, "Encapsulated Bacteria for *In Situ* PAH Bioremediation," FY94 Progress report presented to the SERDP council, Fort Belvoir, VA, May 28, 1996.

**M.T. Montgomery**, R.B. Coffin, L.A. Cifuentes, J.G. Mueller, and B.J. Spargo, "*In Situ* Bioremediation and Efficacy Monitoring," FY96 Progress report presented to the SERDP council, Fort Belvoir, VA, May 28, 1996.

**M.T. Montgomery**, T.J. Boyd, B.J. Spargo, J.G. Mueller, R.B. Coffin, **R.A. Owlett**, D.C. Smith, "Bacterial Productivity in a BTEX-Contaminated and a Creosote-Contaminated Aquifer: A Comparison of  $^3\text{H}$ -leucine and  $^3\text{H}$ -thymidine Incorporation Methods," presentation at the 96th general meeting of the American Society for Microbiology, New Orleans, LA, 1996.

T.J. Boyd, B.J. Spargo, and **M.T. Montgomery**, "Improved Method for Measuring Biodegradation Rates of Hydrocarbons in Natural Water Samples," presentation at the 96th general meeting of the American Society for Microbiology, New Orleans, LA, May 20-24, 1996.

**M.T. Montgomery**, R.B. Coffin, L.A. Cifuentes, J.G. Mueller, and B.J. Spargo, "Encapsulated Bacteria for *In Situ* PAH Bioremediation," FY94 Progress report presented to the SERDP council, Fort Belvoir, VA, May 28, 1996.

**M.T. Montgomery**, R.B. Coffin, L.A. Cifuentes, J.G. Mueller, and B.J. Spargo, "*In Situ* Bioremediation and Efficacy Monitoring," FY96 Progress report presented to the SERDP council, Fort Belvoir, VA, May 28, 1996.

### **Accomplishments**

Assembled and delivered large pulper repair parts to the USS Theodore Roosevelt (CVN 71) at the Naval Operating Base, Norfolk, VA to support deployment.

Refurbished compress melt units (CMUs) 003, 006, 007, and 008; and closed loop cooling units (CLCUs) 003, 005, 006. These machines and miscellaneous repair parts were delivered to USS GEORGE WASHINGTON (CVN 73) for reinstallation.

Assembled and delivered to USS KEARSARGE (LHD3) onboard repair parts for their preproduction CMUs and plastic shredder (PS).

Completed and delivered the final "Shock Test Report on the Solid Waste Management Equipment" (GEO letter 97-055) to SEA 03R16, SEA 03L1, CDNSWC Bethesda (Code 634), and CDNSWC-SSES.

Wrote and delivered copies of the smaller pulp technical manual; to support the follow-on test and evaluation (FOTE) of the SP on board the USS VANDERGRIFT (FFG 48) to SEA 03R16 (A. Nickens) and CDNSWC Bethesda (G. Alexander).

Fabricated and delivered solid waste shredder 005 to CDNSWC Bethesda.

Fabricated and delivered large pulper serial number 011 (LP011) with a control enclosure and spare/repair parts to CDNSWC Bethesda.

Developed dimensional schematics and calculated the center-of-gravity for the six principle large pulper (LP) modules. These schematics were delivered to CDNSWC-SSES which will use these schematics to develop procedures for moving the LP onto ships in hatchable modules.

Procured and delivered two pneumatically-actuated Navy standard ball valves for use in the laboratory oily waste ultrafiltration system to CDNSWC Bethesda. The valves are identical to those installed on the MOPS on board the USS CARNEY (DDG 64).

Procured and delivered a GE FANUC Micro PLC with analog capability and prepared and delivered an electrical schematic drawing to CDNSWC Bethesda (J. Benson) for use in testing and cycling of the valve actuator.

### **3.3 TASK 3 - ENVIRONMENTAL REMEDIATION SITE CHARACTERIZATION**

#### **Technical Requirements**

(1) **Sensors:**

- (a) Full-field Cs vapor magnetometer (equivalent to the DOD Mk22) are the default Multi-Sensor Towed Array Detection System (MTADS) magnetometers. The contractor must evaluate alternative sensors in conjunction with their use with the MTADS concept and their utility in developing extended target analysis and mapping capabilities.
- (b) The contractor must evaluate capabilities of chemical vapor sensors to determine their usefulness for MTADS.
- (c) The contractor must develop sensors for detecting radiological hazards for integration into MTADS.
- (d) The contractor shall propose and evaluate alternative sensor concepts which must be suitable for imaging and integration into MTADS.

(2) Sensor Platforms:

- (a) The contractor shall develop and deliver both a tow vehicle and a sensor support platform suitable for the MTADS prototype.
- (b) The contractor shall develop concepts for both hand held and man-portable sensor detection systems.

(3) Navigation:

- (a) The contractor shall incorporate future improvements in DGPS instrumentation into MTADS.
- (b) The contractor shall evaluate other navigation concepts which might be complementary to DGPS.

(4) Data Acquisition and Preprocessing:

- (a) The contractor shall produce a data acquisition system with capability to acquire the real-time sensor and navigation data compatible with the Unix-based MTADS data analysis system (DAS).
- (b) The contractor shall provide for and maintain compatibility of the data acquisition and preprocessing system with the DAS.

(5) Real Time Display, Survey Guidance, and Target Marking:

The contractor shall design and implement a Realtime DGPS navigation information available in the Tow Vehicle to create a vehicular track and survey progress display.

(6) System Integration:

The contractor shall provide this system integration for: a DGPS navigation system; alternate sensor technologies; a Unix-based data analysis system; theoretical studies culminating in new algorithms and software for near field and extended target analysis.

(7) Demonstrations and Evaluation Surveys:

The contractor shall conduct demonstrations and field evaluations of the MTADS system. The contractor shall provide personnel who are qualified to conduct studies at both EOD sites and toxic/hazardous waste sites.

(8) Documentation:

The contractor shall provide all engineering drawings, electrical and electronic schematics, full operational manuals, and fully documented software.

**Accomplishments**

Attended ESTCP/MTADS Program Review to discuss the Passive Platform and review the Active Platform Development Plan.

Delivered MTADS Active Tow Platform.

**3.4 TASK 4 - AIRBORNE AND MARINE MAGNETIC SITE CHARACTERIZATION**

**Technical Requirements**

The contractor shall conduct a research and development program and provide specified R&D support, including but not limited to the areas associated with this task as enumerated below. The majority of the effort shall be accomplished at the contractor's facility.

Demonstrations and surveys will be conducted at government sites as directed by the COTR.

These sites may be seriously contaminated with explosive and/or chemical ordnance or by the

presence of toxic/hazardous chemicals. Access to these sites will require appropriate training, protective gear and certifications.

(1) Sensors:

(a) The contractor shall deploy airborne and marine mobile sensors (magnetometers) qualified for shallow underwater use as they are envisioned to be deployed in arrays either floating on a surface boom or towed underwater but above the bottom.

(2) Sensor Platforms:

(a) The contractor shall develop marine platforms which must be nonmagnetic, rugged and designed for shallow water environments.

(b) The contractor shall develop airborne platforms that might be remotely controlled or preprogrammed to fly a set grid under control of DGPS navigation systems.

(3) Data Acquisition and Preprocessing:

(a) The contractor shall produce a data acquisition system with capability to acquire and integrate real-time sensor and navigation data compatible with that being developed for MTADS with adaptation for the special requirements of this application.

(b) The contractor shall directly apply the MTADS data acquisition to the marine mobile system with the additional data stream to record the distance from the bottom to the sensor heads.

(4) Navigation:

The contractor shall improved DGPS capabilities for use in altitude control for the platform and sensors.



(5) Demonstration and Evaluation Surveys:

The contractor shall conduct demonstrations and field evaluations of the airborne and marine MTADS systems.

Accomplishments

No work was performed on this project and no charges were incurred.